Original

Relationship between the Type of Feeding Behavior of Termites and the Acoustic Emission (AE) Generation*[1]

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Abstract——Three pest termite species, *Coptotermes formosanus* Shiraki, *Reticulitermes speratus* (Kolbe) and *Cryptotermes domesticus* Haviland were used to investigate the relationship between the types of feeding behavior and the generation of acoustic emission (AE) using a charge coupled device (CCD) camera under AE monitering. Three types of feeding behavior, "pulling", "cutting" and "scraping", basically using the mandible and the maxillae, were observed with the CCD camera. When pulling behavior was observed, AEs of larger amplitude were interruptedly detected. Frequent AEs of lower amplitude were detected when cutting and scraping were observed.

Keywords : subterranean termite, drywood termite, feeding behavior, CCD camera, acoustic emission

1. Introduction

To detect the feeding activity of termites, the feasibility of acoustic emission (AE) monitoring has been discussed[1–7].

AE is the elastic wave produced by the strain energy releasing in the process of fracture of a material and is propagated through it. The theoretical background of AE for detecting the feeding activity of termites is to grasp the feeding activity as the micro-fracture of wood.

However, no one had ever described the relationship between the feeding behavior and the AE generation directly, except for Fujii and co-workers[8]. They observed the feeding behavior and the mechanism of AE generation using a CCD camera under AE monitoring, and concluded that AEs were detected only when the termites bit or nibbled at the wood. Unfortunately, their investigation was limited to a single termite species, *Coptotermes formosanus* Shiraki, and the magnification of the camera was not so high.

To discuss the relationship between the types of the feeding behavior and the AE

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generation, a high-magnification CCD camera was employed, under simultaneously using three termite species.

2. Materials and Methods

The experimental set-up used in the present investigation is shown in Figures 1 and 2.

2.1 CCD camera

A compact color CCD (Charge Coupled Device) camera (KEYENCE, VH-6110) with a valuable magnification lens (25×–175×) was used for the observation of the feeding behavior of termites. As shown in Fig. 2, observation unit was kept in an air-conditioned chamber (30℃, 80% R.H.), and the magnification and the focus were remotely controlled from the outside of the chamber. The pictures were transferred to CRT monitor and recorded with a video recorder.

2.2 Termites

Workers or pseudergates of two subterranean termite species, *Coptotermes formosanus* Shiraki and *Reticulitermes speratus* (Kolbe), and a drywood termite, *Cryptotermes domesticus* Haviland, were used as test insects. Before the experiment, they were starved for 1–2 days to activate their wood-feeding.

2.3 Wood specimen

A rectangular hole of about 5–6 mm wide, 7–8 mm long, 2 mm deep was made in a surface of an air-dried small specimen of white seraya (*Parashorea* spp.), measuring 35 mm

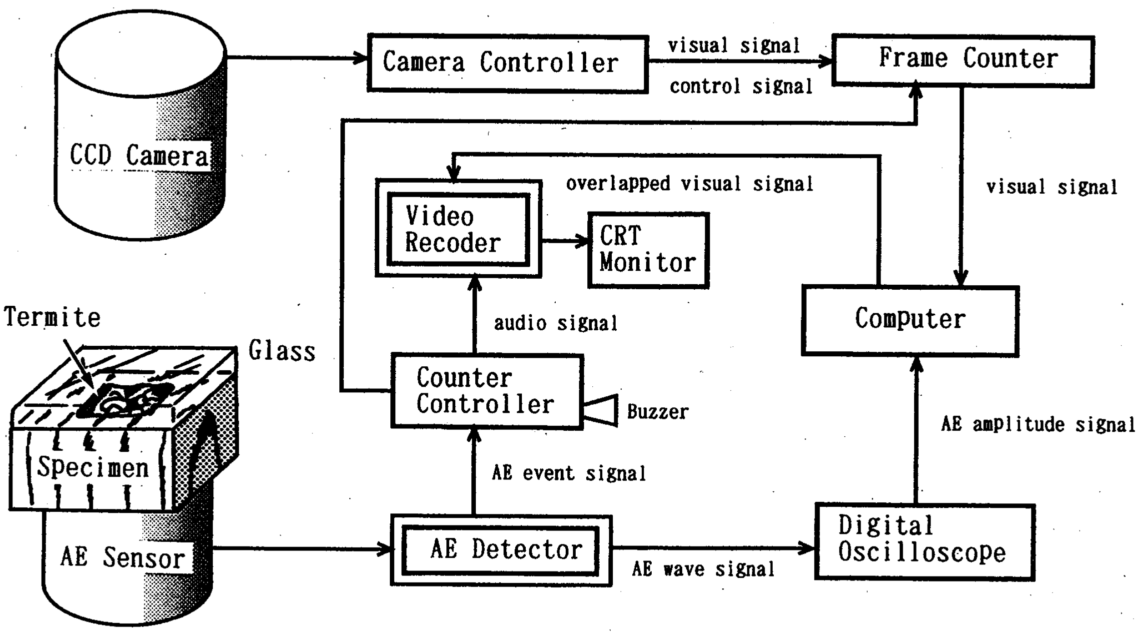


Fig. 1. Schema of the experimental set-up for AE monitering through wood-feeding behavio of termites.

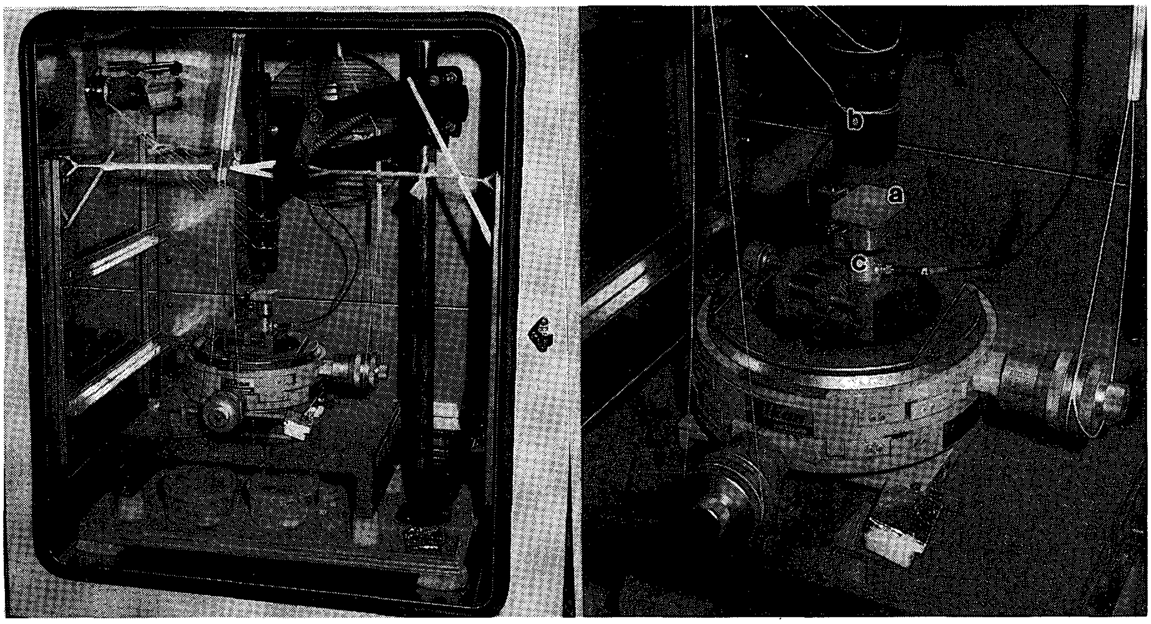


Fig. 2. Left : Air-conditiond chamber containing the observation unit of feeding behavior of termites. Right : Magnification of the observation unit. a : Wood specimen loaded by a warker, b : CCD camera head, c : AE sensor

(R)×25 mm (T)×7 mm (L). A worker or a pseudergate was put in the hole. And the hole was covered with a transparent glass.

2.4 AE monitoring

A piezoelectric AE sensor of resonant frequency of 140 kHz (NF, AE-901s) was attached on the opposite surface to the hole with hot-melt adhesive. The signal from the sensor was amplified about 52 dB, filtered by a high-pass filter of cut-off frequency of 100 kHz and discriminated at a threshold voltage of 0.1 V with the AE apparatus (NF, AE-9501).

2.5 Recording of AE generation on the picture

"Frame number" of video apparatus that automatically increased every one-sixtieth second and "scene number" that increased at each resetting of the frame number were overlapped on the picture taken by the camera using a "frame counter" apparatus. Using another "counter controller", these numbers were controlled so that frame counter was reset by the AE event signal (TTL negative logic) from the AE apparatus, and restarted counting just after the resetting. With this function of the counter controller, the scene number in the picture increased according to the AE generation and the time (the number of video frames ran) between two successive AE events. In addition, a buzzer was beeped according to the AE generation, and the beep signal was sent to the video recorder. By using a personal computer, together with an interfaceboard for super-impose, figures of the peak to peak (p-p)

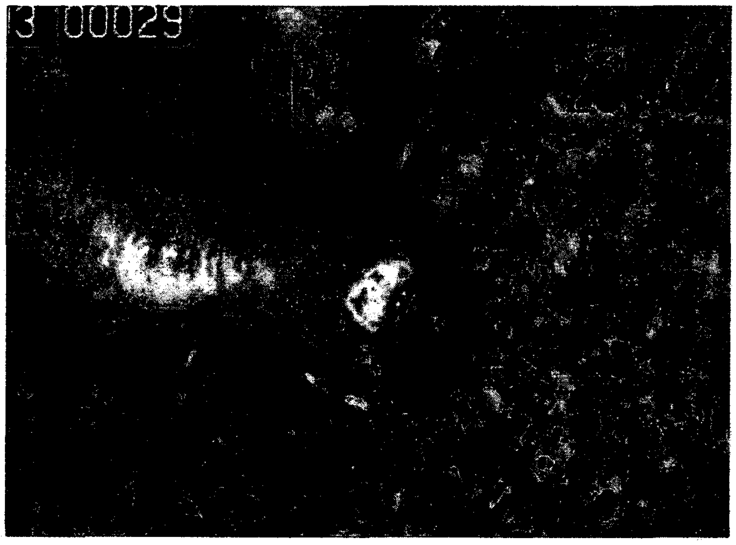


Fig. 3. Recorded picture of termite (*Coptotermes formosanus*) in CCD camera. Numbers at upper left corner represent the frame number. Numbers at upper right corner show the p-p amplitude of AE.

amplitude of AEs obtained by the oscilloscope were simultaneously imposed on the recorded pictures (Fig. 3).

3. Results and Discussion

3.1 Diffrentiation of the feeding behavior

In this study, the feeding behavior of termites was differentiated into the following three types. The movements of mandible and maxillae on each behavior are shown in Fig. 4.

Pulling (Fig. 4-①)

A wood fragment was pulled by the maxillaes while mandibles were stuck deep into the wood. During this behavior termite body was rocked and twisted. The bitten fragments were sometimes spewed.

Cutting (Fig. 4-①)

A fragment was cutt off from wood by mandibles, when the fragment was held by maxillaes. This behavior was often seen before "pulling".

Scraping (Fig. 4-②)

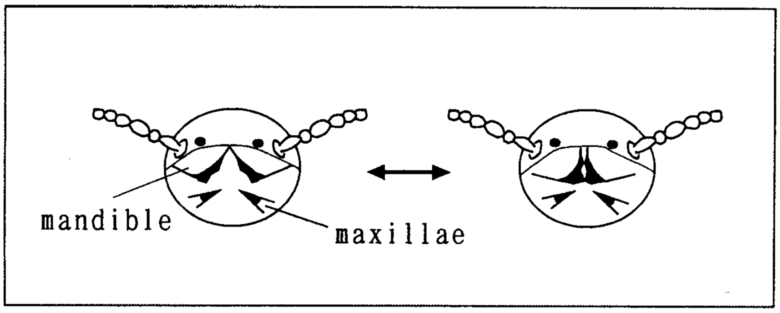
Scraping of wood is the feeding behavior using all organs of mouth part. It was also seemed as searching of the suitable point to hook the maxillae.

3.2 Observation of the feeding behavior on each termite species

Coptotermes formosanus

Three types of the feeding behavior were recorded for workers of Co. formosanus. For about 0.5–1 hour from the start of the observation, the termite was just moving around inside

① Pulling · Cutting



② Scraping

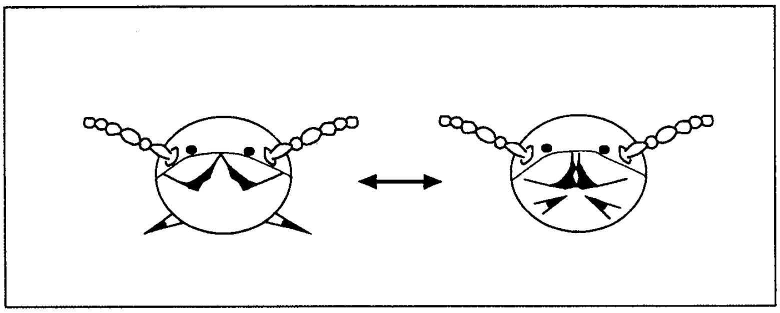


Fig.4. Movement of mandible and maxillae on each feeding behavior.

the hole, touching the wood surfaces with the antennae. After that, the feeding behavior commenced. As water was not supplied during the observation, vigorous action of termites lasted only for about 1–2hours.

Reticulitermes speratus

Only "pulling" was observed for workers of *R. speratus*. Since this termite needed dampwood, several drops of water were pipetted into the hole before loading of the test individual. However the termite could move vigorously only for 0.5–1 hour, when the hole was kept wet.

Feeding on dampwood might require only "pulling" behavior for this species.

Cryptotermes domesticus

Only "pulling" was observed for pseudergates of *Cr. domesticus*. Since this termite was dry-wood termite, observation was available for longer than the other two species.

Dry wood termites generally showed the lower basal metabolic rate than subterranean termite species, therefore to do only "pulling" was considered to be suitable for *Cr. domesticus*.

3.3 Relationship between the feeding behavior and AE generation

AEs were almost detected only when any feeding behavior was observed, but every feeding activity not always generated the AE. Table 1 shows the relationship between the counts of the stickings of the mandible and the detected AEs per minute on each behavior. All termite species steadily performed each behavior in 45–70 counts of mondible-sticking per minute, although the number of AE generation varied with the type of behavior.

Table 1. Relationship between the counts of the stickings of the mandible and the detected AEs on each behavior.

Termite	Feeding behavior	Obsevation period (sec)	Counts of the stickings of the mandible per minute (A)	AE generation per minute (B)	Ratio of B to A (%)
Co. formosanus	Pulling	210	52.9	7.1	13.5
	Cutting	137	72.7	12.7	17.5
	Scraping	79	74.4	26.6	35.7
R. speratus	Pulling	232	55.3	8.3	15.0
Cr. domesticus	Pulling	262	44.9	7.1	15.8

Table 2. Relationship between the feeding behavior and the AE's peak to peak amplitude on each termite.

Termite	Feeding behavior	Number of samples	Average p-p amplitude (mV)	Standard Deviation
Co. formosanus	Pulling	25	556	327
	Cutting	29	323	142
	Scraping	35	311	92
R. speratus	Pulling	32	389	159
Cr. domesticas	Pulling	31	342	155

"Scraping" generated the largest number of AEs (26.6/min), followed by "cutting" (12.7/min). "Pulling" by any species produced only 7–8 AEs per minute. Calculating the AE generation/mandible-sticking ratio, "scraping" was ranked first and the other types of the behavior showed less than half values. Among the three types of the behavior, "scraping" was a most intensive action using all organs in mouth part. This might cause the most frequent AE generation. The reason why the smaller number of AE take place in "pulling" and "cutting" in comparison with "scraping" is not clear from the present observation.

Relationship between the feeding behavior and the p-p amplitude of AE is shown in Table 2. Generated AEs in "pulling" by *Co. formosanus* showed the largest p-p amplitude (556 mV in average) with the highest deviation. "Pulling" consists of two sub-behavior: sticking of mandible into wood and pulling of wood fragments by the maxillae. The difference of p-p amplitude of AEs generated by each sub-behavior probably resulted in higher deviations found here. From the detailed observations, relaxing of the powerful pulling of wood fragment by the maxillae of *Co. formosanus* seemed to generate the AEs of the larger amplitude. The lower amplitude AEs (350–400mV in average) generated by "pulling" behavior of *R. speratus* and *Cr. domesticus* might be due to the lower feeding- activity of these species than that of *Co. formosanus*. Among the feeding behavior of *Co. formosanus*, "pulling" generated AEs of 1–7 times larger amplitude than did "cutting" and "scraping".

The present results suggested that AE generation and its p-p amplitude were clearly related to the feeding behavior of termites, although the number of samples were still limited. "Pulling" generated the larger but the smaller number of AEs, while "cutting" and "scraping" yielded the smaller but the larger number of AEs. In order to achieve the general characterization of AEs by wood-feeding behavior of termites, further tests are necessary on much more wood speacies and replicates of termite individuals. In addition the contribution of other organs such as maxillae should be investigated in more detail.

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